VERIFICATION OF THE PRESSURE TRANSDUCERS

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Abstract: This work treats verification of the pressure transducers, having the accuracy class between 0.2 and 0.6, with unified (4 … 20) mA output signal and linear transfer function.

Keywords: *transducers, linear function, reduced error, hysterezis, repeatability, conformity*

1. INTRODUCTION

The transducer is a device that provides an output quantity having a determined relationship to the input quantity [1].
The transducer converts the input pressure into direct current or voltage at output.
Generally speaking a pressure transducer has some components as follows:
the elastic sensing element, directly in contact with the measurand,
electrical convertors and intermediate devices,
correction devices for errors due to influence quantities,
final device for output signal.
The principal characteristics of the transducers are:
accuracy (nonlinearity, hysteresis, drift),
range of indication (upper range limit),
calibrated range,
the shape of transfer curve,
the limits for ambient temperature in use,
the coefficient of temperature corrections.
The transfer curve of the transducer means the relation between input signal and output signal. This relation can be a mathematical function, an table with numerical values or a graphic curve.
Usually, the transfer curve is a linear curve.
The transducers have a range of indication with a lower range limit and an upper range limit; into this range of indication can be fixed many measured ranges, characterized by lower range value and upper range value. In the measured range many calibrated spans can be fixed.
Number of accuracy class of the transducers [3], means, in the same time, the maximum accepted error, from calibrated span, in percentage.
Optional, the transducer can be equipped with:

- local indicated analog, digital or bar-graph apparatus,
- microprocessors and convertors to link the output signal with computers,
- another supplementary transducers: for static pressure, temperature and so on.

The pressure transducers can measure:

- relative pressure,
- absolute pressure,
- differential pressure.

2. TERMS REGARDING OF VERIFICATION

On the case of transducers involved in verification process the following information shall be indicated:
name or designation of the manufacturer,
type or model,
serial number and year,
measuring range specified by the manufacturer,
accuracy class,
output signal form,
power supply,
type approval number.
The following environmental conditions are properly for verification:
temperature: (20 ± 2) °C,
maximum relative humidity: 80 %
atmospheric pressure: (86 … 106) kPa
Electrical power supply shall to have following tolerances:

- nominal voltage: ± 1 %
- nominal frequency: ± 1 %
- harmonical distorsions, in a.c.: < 5 %
- distorsions, in d.c.: < 0.1 %

It is necessary to ensure that no vibrations, shocks, sources of electromagnetic radiation are in the vicinity of the transducers.

3.METHOD OF VERIFICATION

Verification is a testing procedure by whom is established if a measurement device comply with requirements of legal recommendations which are applicable.
Verification method is a direct comparison between indications of the transducer and the indications of the standards.
For transducers verification two standards are used; one for the input signal and another for the output signal. In case of the transducer measuring absolute pressure a barometer is needed. The standards for input signal are pressure standards: pressure

balances, pressure calibrators, manometers with elastic sensing element, liquid manometers, barometers.

The pumps used to create pressure in the system of verification, have to create a slow pressure up to the maximum pressure needed without shocks.

The standards for output signal are voltmeters, electrical multimeters and resistors.

Standards are chosen keeping in mind that the expanded uncertainty (the input standard combined with the output signal) have to be less than the third part of the maximum admissible error of the transducer.

In figure 1 is presented the scheme of a verification.

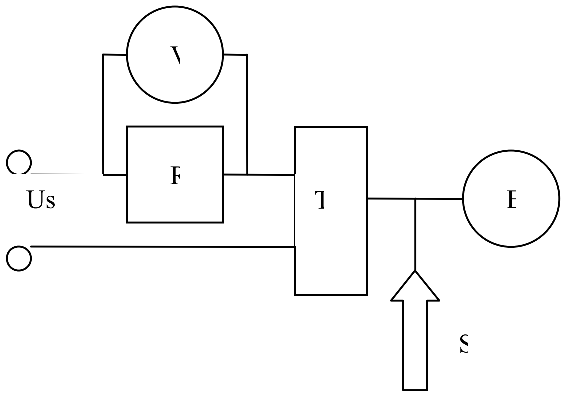

Figure 1 – The scheme of the transducer verification

Where:

S	is the pressure source
E	is the pressure standard
T	is the transducer
R	is the standard resistor
V	is the standard for output signal
Us	is power supply, on d.c.

Before performing verification some precautions have to be take into account:

any item of the equipment shall be placed in the room where verification will be performed at least 6 hours before starting the operation, in order to reach thermal equilibrium of the whole system,

the input standard and transducer shall be at the same level and the difference in the levels shall be considered when calculating head corrections of the measured results,

the transducer shall to be mounted in work position,

the pressure fluid shall be at same temperature as the ambient air,

no leakage shall appear along the pipes,

the pipes shall to be shortest long possible and with sufficient cross section in order to transfer easily the working fluid between the connected instruments.

In a verification of a transducer a cycle of measurements is performed.

A cycle means to increase the pressure slowly, from zero to maximum limit of the transducer, keeping the maximum pressure 5 minutes and then decrease the pressure slowly to zero.

The verification is performed in 11 points of pressure, equal distributed in the range, covering the lower and upper limit of the measurement range, respectively (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100) % from the range.

4.METROLOGICAL CHARACTERISTICS

Performing this operation some parameters have to be determinate:

- the transfer function,
- the reduced errors,
- the hysterezis errors,
- the linearity errors.

The reduced error means the difference between the effective curve value and the nominal curve value.

4.1. The transfer function

The input signal, in this case the pressure, has values equal distributed in the range, according to the formula:

$$X_i = X_0 + i\frac{X_m - X_0}{n} \qquad (1)$$

Where:

Xi is the value of the input signal,

Xo is the minimum value of the input signal,

Xm is the maximum value of the input signal,

i is the running number of the input signal (i = 0,1, …,11).

The output signal has values, according to the formula:

$$Y_i = Y_0 + i\frac{Y_m - Y_0}{n} \qquad (2)$$

Where:

Yi is the value of the output signal, corresponding to the input signal Xi,

Yo is the minimum value of the output signal,

Ym is the maximum value of the output signal,

i is the same as before

In this case the transfer function [2] is a result from (1) and (2) formulas combination:

$$Y_i = Y_0 + \frac{Y_m - Y_0}{X_m - X_0}\left(X_i - X_0\right) \qquad (3)$$

Where the terms have the same signification as before.

4.2 Reduced errors

Reduced errors [2] are the errors expressed, from the measurement range for output signal, in percentage. The intrinsic errors, the errors performed in reference conditions, [3] are calculated using the formulas:

$$E_{ic} = y_{ic} - Y_i \qquad (4)$$
$$E_{id} = y_{id} - Y_i$$

Where:

y_{ic} is the indication of the transducer with increasing pressure

y_{id} is the indication of the transducer with decreasing pressure

The reduced errors are calculated using the formulas (as percentage from the range of output signal):

$$e_{ic} = \frac{E_{ic}}{Y_m - Y_0} x100$$
$$e_{id} = \frac{E_{id}}{Y_m - Y_0} x100 \qquad (5)$$

The medium reduced error is:

$$\overline{e_i} = \frac{1}{2}\left(e_{id} - e_{ic}\right) \qquad (6)$$

4.3 The hysteresis errors

The hysteresis error means the difference between the effective curve value with increasing pressure and the effective curve value with decreasing pressure, expressed as percentage from the range of output signal.
The hysterezis error is calculated using the formula:

$$h_i = \left|e_{id} - e_{ic}\right| \qquad (7)$$

4.4. The linearity errors

The curve of terminal – based linearity [4] is expressed by formula:

$$y_i = y_0 + \frac{y_m - y_0}{X_m - X_0}\left(X_i - X_0\right) \qquad (8)$$

Where:
y_i is the value for output signal corresponding to the input signal Xi

$$y_0 = \overline{e_0}$$
$$y_m = \overline{e_m}$$

Nonlinearity, in the case of the curve of terminal – based linearity is expressed as follows:

$$z_i = \overline{e_i} - y_i \qquad (9)$$

4.5 The uncertainty

Each non-linearity has an associated uncertainty. The uncertainty has at least three components:

- the uncertainties of the input signal standards,
- the uncertainties of the output signal standards,
- hysteresis and repeatability of the measurements.

In order to calculate repeatability of the measurements, at the 50% of the range, three cycles of measurements are performed.
The repeatability calculated in this point is consider to be the same for all points of pressure.
The uncertainties of the input and output signal standards are taken from the calibration certificates for these standards.
For example, for input signal pressure standard the uncertainty is:

$$u(p) = \frac{U(p)}{2} \qquad (10)$$

If the output signal is in mA (using a voltmeter and a resistor), than the uncertainty is:

$$u^2(I) = \frac{I^2}{3} \cdot \left[\left(\frac{u(V)}{V}\right)^2 + \left(\frac{u(R)}{R}\right)^2\right] \qquad (11)$$

The uncertainty of the hysteresis is:

$$u(h_i) = \frac{h_i}{2\sqrt{3}} \qquad (12)$$

The uncertainty due to the repeatability of the measurements is:

$$u_A = t_r \cdot s_i \qquad (13)$$

Where:

s_i is the repeatability

t_r is the coefficient from the Student distribution

CONCLUSIONS

A transducer comply with the requirements of legal recommendations which are applicable if the non-linearity, cumulated with the associated uncertainty, in each point of measurement, don't exceed the admissible maximum error.

References

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